CHAPTER 6
THE X-RAY IMAGING SYSTEM

Three Principal Parts of X-ray Imaging System
- X-ray Tube, Operating Console & High Voltage Generator

Radiographic X-ray Tube
- It is attached to an overhead movable crane assembly
- *Location:* examination room

Fluoroscopic X-ray Tube
- It is located under the examination table

Examination Table
- It must be transparent to x-rays as possible
- *Composition:* carbon fiber (strong & absorbs little radiation)

Fluoroscopic Table Tilt
- *Tilt:* 90/30
- 90 degrees to the foot side
- 30 degrees to the head side

High Voltage Generator
- It is housed in an equipment cabinet positioned against a wall
- It is always close to the x-ray tube

OPERATING CONSOLE

Operating Console
- Most familiar to the radiologic technologist
- It is used to control the x-ray tube current & voltage applied to the x-ray tube
- It provides control of line compensation, kVp, mA & exposure time

Radiation Quantity
- The number of x-rays
- The intensity of the x-ray beam
- *Units:* mR or mR/mAs

Radiation Quality
- The penetrability of the x-ray beam
- It is expressed in kVp or HVL (more precisely)

Line Compensator
- It measures the voltage provided to the x-ray imaging system

AUTOTRANSFORMER

Autotransformer
- It consists of only one winding of wire & one core
- *Function:* supplies a precise voltage to the filament circuit & high-voltage circuit
- It controls the kVp
- *Location:* operating console
- Step up voltage approximately twice the input voltage value

Primary Connection
- It conducts the input power to the autotransformer

Autotransformer Law
- It states that the voltage receive & provide by the transformer is directly proportional to the number of turns
- *Formula:* $V_s/V_p = N_s/N_p$

Adjustment of Kilovoltage Peak (kVp)
- Major & minor kVp

kVp
- It determines the quality of the x-ray beam

kVp Meter
- It reads voltage (not kVp)
- *Location:* output terminals of the autotransformer

Prereading kVp Meter
- It allows the voltage to be monitored before an exposure

X-ray Tube Current
- It is measured in milliamperes (A)

Filament Temperature
- It determines the number of electrons emitted by the filament

Filament Current
- It controls the filament temperature
- It is measured in amperes (A)
- *Range:* 3-6 A

Filament Circuit
- It controls x-ray tube current

Space Charge Effect
- A phenomenon of the space charge that makes it difficult for subsequent electrons to be emitted by the filament because of electrostatic repulsion

Space Charge
- Electron cloud near the filament

Thermionic Emission
- The release of electrons from a heated filament

Precision Resistor
- It is used to reduce the voltage to a value that corresponds to the selected milliamperage

Falling Load Generator
- Design in which exposure factors are adjusted automatically to the highest mA at the shortest exposure time allowed by the high-voltage generator
- Exposure begins at maximum mA & it drops as the anode heats
- *Result:* minimum exposure time

mAs
- The product of x-ray tube current (mA) & exposure time (s)
- A measure of electrostatic charge (C)

mA Meter
- It monitors the x-ray tube current
- It is connected at the center of the secondary winding of the high-voltage step-up transformer
- *Rationale:* ensures electrical safety

Filament Transformer
- *Full Name:* Filament Heating Isolation Step-down Transformer
- A step down transformer
- *Functions:*
  - Received the voltage from the mA selector switch
  - Steps down the voltage to approximately to 12 V
  - Provides the current to heat the filament
- *Primary windings:*
  - Thin copper
  - Current: 0.5-1 A
  - Voltage: 150 V
- *Secondary windings:*
  - Thick
  - Current: 5-8 A
  - Voltage: 12 V

EXPOSURE TIMERS

Guard Timer
- It terminates an exposure after a prescribed time (6 s)

Timer Circuit
- It consists of an electronic device
  - Make & break the high voltage across the x-ray tube
  - Always done on the primary side
    - *Rationale:* lower voltage

Four Types of Timing Circuits
- Synchronous Timer, Electronic Timer, mAs Timer & Automatic Exposure Control

Synchronous Timer
- A precision device designed to drive a shaft at precisely 60 revolution per second
- It cannot be used for serial exposures

Electronic Timer

- Most sophisticated, most complicated & most accurate (as small as 1 ms)
- It allows a wide range of time intervals to be selected
- It is used for rapid serial exposures

Most exposure timers are electronic & are controlled by a microprocessor!

mAs Timer

- *Functions:*
  - Monitors the product of mA & exposure time
  - Terminates exposure when desired mAs value is attained
  - Provides the highest safe tube current for the shortest exposure for any mAs selected
- *Location:* secondary side of the high-voltage transformer
- *Applications:*
  - Falling-load
  - Capacitor discharge imaging system

Automatic Exposure Control (AEC)

- A device that measure the quantity of radiation that reaches the image receptor
- It automatically terminates the exposure when the image receptor has received the required radiation intensity

Solid-state Detectors

- It is used to check timer accuracy (as short as 1 ms)

HIGH VOLTAGE GENERATOR

High Voltage Generator

- It increases the output voltage from the autotransformer to the kVp necessary for x-ray production

Three Primary Parts

- High Voltage Transformer, Filament Transformer & Rectifiers

High Voltage Transformer

- A step-up transformer
- Secondary Voltage (kVp) > Primary Voltage (V)
- Secondary Current (mA) < Primary Current (A)
- Secondary Windings > Primary Windings
- *Voltage Waveform:* sinusoidal
- *Amplitude:* only difference in the primary & secondary waveform

Turns Ratio

- The ratio of the number of secondary windings to the number of primary windings
- *Examples:* 500:1 & 1000:1
- Directly proportional to the voltage
- Inversely proportional to the current

Voltage Rectification

- It ensures that electrons flow from cathode to anode only

Rectification

- The process of converting alternating current (AC) to direct current (DC)

Rectifier

- An electronic device that allows current flow in only one direction

Diode

- An electronic device that contains two electrodes

Valve Tube

- A vacuum tube (original rectifier)
- It replaced by solid-state rectifier
  - *Composition:* silicon

Semiconductor

- Lies between insulators & conductors
- *2 Types:* p-type & n-type

P-type Semiconductor

- Have loosely bound electrons (*free to move*)
- Have spaces called holes (*no electrons*)

- *Holes:* as mobile as electrons

Solid-state p-n Junction
- N-type material placed in contact with p-type crystal
- It conducts electricity in only one direction
- *Solid-State Diode:* a rectifier

Electron flow is used when medical imaging systems are described!

Half-Wave Rectification
- The voltage is not allowed to swing negatively during the negative half of its cycle
- *Diodes:* 0, 1 or 2
- 60 pulses/second
- *Disadvantages:*
  - It wastes half the supply of power
  - It requires twice the exposure time

Full-Wave Rectification
- The negative half-cycle corresponding to the inverse voltage is reverse
- *Diodes:* 4
- 120 pulses/second
- *Advantage:*
  - Exposure time reduced in half

Single-Phase Power
- It results in a pulsating x-ray beam
- *Disadvantage:*
  - X-ray produced has a value near zero

Three-Phase Power
- The voltage impressed across the x-ray tube is nearly constant
- 6 pulses/1/60 second
- *Advantage:*
  - Voltage never drops to zero during exposure
- *Disadvantages:*
  - Its size & cost

Initiation Time
- Starting an exposure

Extinction Time
- Ending an exposure

High Frequency Generator
- It produces a nearly constant potential voltage waveform
- *Advantages:*
  - Much smaller & less costly & more efficient
  - Improves image quality at lower patient radiation dose
- It uses inverter circuits

Inverter Circuit
- A high-speed switchers or choppers that convert DC into a series of square pulses

Full-wave rectification or high-frequency voltage generation is used in almost all stationary x-ray!

Capacitor Discharge Generator
- Tube voltage falls during exposure
- Approximately 1 kV/mAs

Grid-Controlled X-ray Tube
- An automatic lead beam stopper
- It stops continues x-ray emission of capacitor bank
- It is designed to be turned on & off very rapidly
- *Applications:*
  - Portable capacitor discharge imaging systems
  - Digital subtraction angiography
  - Digital radiography
  - Cineradiography
- *Grid*: it refers to an element in the tube that acts as a switch

Less Voltage Ripple
- Greater radiation quantity
  - Higher efficiency of x-ray production

- Greater radiation quality
    - Fewer low-energy projectile electrons pass from cathode to anode

CHARACTERISTICS OF HIGH FREQUENCY X-RAY GENERATORS

Frequency Range	Inverter Features
<1 kHz	Thyristors
1-10 kHz	Large silicon-controlled rectifier
10-100 kHz	Power field effect transistors

Voltage Ripple

- Means of characterizing voltage waveforms

Waveform	Ripple	Voltage
Single Phase:		Varies from zero to maximum
Half-wave	100%	
Full-wave	100%	
Three-Phase:		
6-pulse	14%	Never falls below 86% of maximum value
12-pulse	4%	Never falls below 96% of maximum value
High Frequency	< 1%	Never falls below 99% of maximum value

Power Rating (kW)

- *Formula:* for three-phase & high frequency
    - (mA x kVp)/1000
- *Formula:* for single-phase
    - (0.7)(mA x kVp)/1000

Three Main Section of X-ray Imaging System

- X-ray tube, Operating Console & High-Voltage